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THE NUMERICAL SIMULATION AND EVALUATION OF AIRCRAFT ENGINE AXIAL FLOW TURBINE USING NUMERICAL TECHNIQUES

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ABSTRACT

This research aims to improve the efficiency of an axial flow turbine by improving the boundary conditions. In the baseline paper, Sherwood number, Nusselts number for a given flow were determined. The pressure ratio was not considered in the paper. Research has been done to improve the values by considering the pressure difference which was neglected in the base line paper. Axial flow turbines expand the flow passing through it. Losses like tip losses, efficiency losses and loss on blades due to heat are high and needs to be looked after. A comprehensive literature study was carried out for the better understanding of axial flow turbines, recent developments and to analyze the control of loses.

KEYWORDS: Axial Flow Turbines, ANSYS Fluent, Sherwood Number, Nusselt Number, Tip Losses & Efficiency

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Original Article

INTRODUCTION

Axial flow turbine expands the flow which passing through it in any medium. A set of blades are mounted on a shaft and are placed in the direction of the air. The air is expanded by the blades. If the air is flowing along the blade and in the direction of air, it is called axial flow turbine. A real life turbine design can be seen in Figure 1.

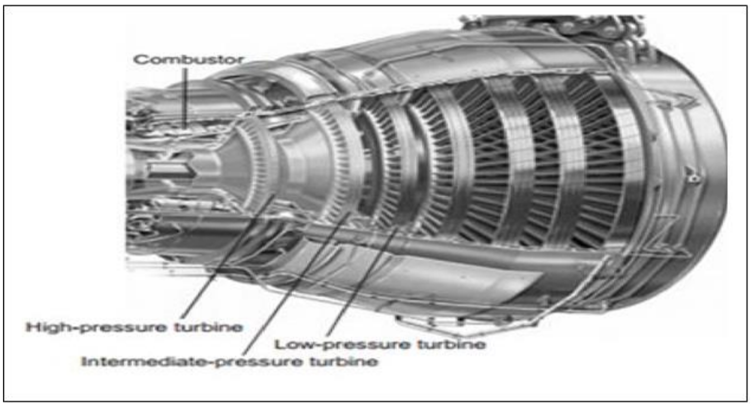

Figure 1: Representation of Aircraft Engine Axial Flow Turbine [32]

The blades of the turbine experience heat change over them. This convection and changes in temperature is expressed below using a relation between Reynolds Number, Nusselts Number & Sherwood Number.

LITERATURE REVIEW

Theoretical Analysis on Axial Flow Turbine

The theory of axial flow turbines has been discussed in a sophisticated manner. Various defects were discussed to which different types of solutions have been found out[7,10]. Few of the theoretical study that took place is on the two stage system turbine system under steady and pulsating flow, flameless combustion towards gas turbines and many other such departments of physical strains that can affect the turbine[1,3,5,8]. Many positives were also been mentioned such as increasing the number of stages in a turbine from 2 to 5 without leaving the effective cantilever arrangement using the Organic Rankine Cycle (ORC). The stages were limited to 3 or 4 due to rotor dynamic stability effected by the overhung mass proportionally increased by the number of stages. When it comes to managing power the partial admission turbine plays an important role as it strengthens the unsteady flow. Several other theories were used throughout the ages and have been improving and developing the present day turbines with higher efficiency [2,4,6,9].

Numerical Analysis of Axial Flow Turbine

Simulations and experimentation of the turbines that have surfaced over the years such as when the axial flow turbines were compared with the cross flow turbines [11-17]. The axial flow turbine were influenced by a phenomenon which is instable and leads to a significant turbulent flow. The mean span wise velocity field is observed to be much more related to cross flow turbine's wake recovery. Guide lines for the design optimization of efficient high supersonic passages were also derived [18-20].

Experimental Analysis on Axial Flow Turbine

The papers above have given brief description about how the experiments have been performed previously. CFD (Computational Fluid Dynamics) investigations played very important role in determining the outcome of the experimental setup and efficiency of the turbine. Software research gave the optimal tip speed ratio and design tip speed ratio [22,29-30]. One unique paper made use of Fast Fourier Transform (FFT) method to analyze the static pressure fluctuation. The main software that was used to simulate the turbine model before making the experimental model were Catia to make the model and Ansys to simulate flows[21,23,24-28].

METHODOLOGY

Modelling of Axial Flow Turbine

Investigation has been performed on the turbine blade and hubwall to study the effect of secondary flows on mass transfer. A linear cascade with thirty six blades is used to conduct tests as shown in [figure 1]. A turbine model with 36 blades has been designed in BLADEGEN. SST k-omega model is evaluated by comparing with experimental results from the paper cited as [31]. In the present study, the flow is investigated numerically. The design can be seen in Figure 2

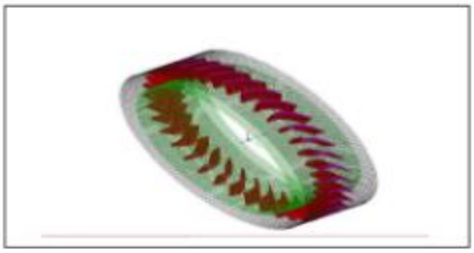

Figure 2: Model Generated with Thirty-Six Blades

Flow Setup

Ansys FLUENT was used for simulation as mentioned in the paper. Solver type was pressure based and steady flow conditions were given. The energy equation was used to measure temperature contours and see the heat flow on the blade. The flow was turbulent and “k- omega (2 eqn), SST” conditions were given

Table 1: Boundary Conditions

Flow material used	Air at 25
Inlet Velocity	0.36 m/s
Reynolds number	600000
Inflow Turbulent Intensity	0.2%
Dynamic viscosity	1.46e-5 m^2/s
Energy Prandlt number	2.28
Outlet condition	Outflow
Chord (C)	184mm

RESULTS AND DISCUSSIONS

These results are suited for validation of numerical codes, an accurate technique was used which will enable us to apply accurate boundary conditions and prevent any errors possible. Prandtl number of 2.28 has been used for simulation. In the paper Nu = Sh was proved. Simulations were performed to validate the data satisfying all the conditions. The Sh decreases sharply as the boundary layer increases in the streamwise direction on the blade surface. By the experimental and numerical results comparison can be made to show the calculated and computed Sherwood number using the line plots. Blades are shown by the rectangle bars in the figure above.

$$Re = \frac{\rho N D^2}{\mu} = \frac{\rho V D}{\mu}$$ (Equation 1)

$$Nu = (Re, Pr)$$ (Equation 2)

$$Nu_x = 0.332 Re_x^{1/2} Pr^{1/3}, \ (Pr > 0.6)$$ (Equation 3)

$$Nu_x = 2 \times 0.332 Re_x^{1/2} Pr^{1/3}, \ (Pr > 0.6)$$ (Equation 4)

$$Sh = \frac{h}{D/L} = \frac{Convective\ mass\ transfer\ rate}{Diffusion\ rate}$$ (Equation 5)

The system is fully turbulent over Re=10000

Where, L - characteristic length (m)

D - mass diffusivity (m2. s−1)

h - convective mass transfer film coefficient (m. s−1)

Using dimensional analysis, it can be defined as a function of the Reynolds and Schmidt number.

Results show that the flow is good near the wall region. A vortex was formed at the blade leading edge. The pressure migrates towards the suction trailing edge, where it meets the trailing edge vortex. Further downstream heat effect is observed. The transfer rates are related to the passage. The simulation of the blade at the leading edge vortex captures the enhancement of heat transfer. The calculations involving Sherwood and Nusselts number is done by using (Equation.1), (Equation. 2), (Equation. 3) & Equation. 4)”.

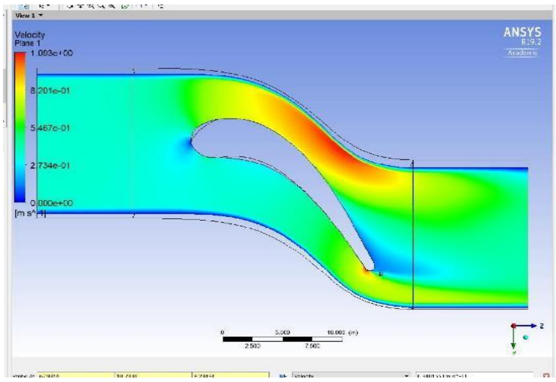

Figure 3: Velocity Contour on TURBINE blade

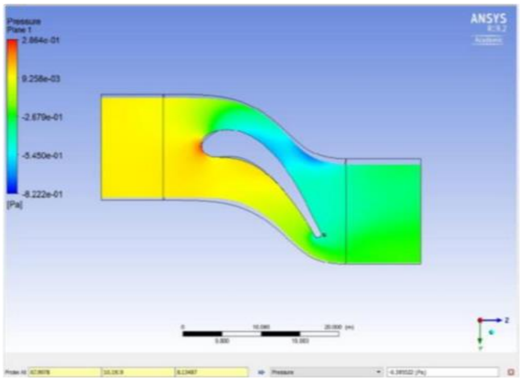

Figure 4: Pressure Contour on Turbine Blade

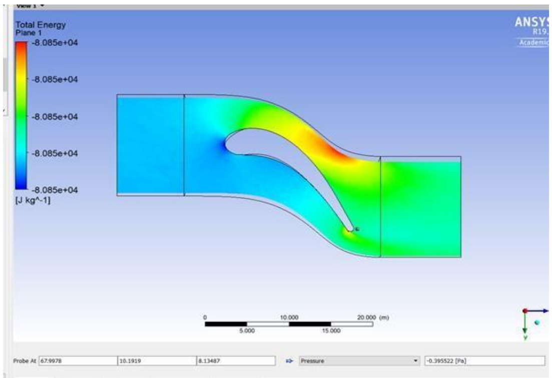

Figure 5: Total Energy on Turbine Blade

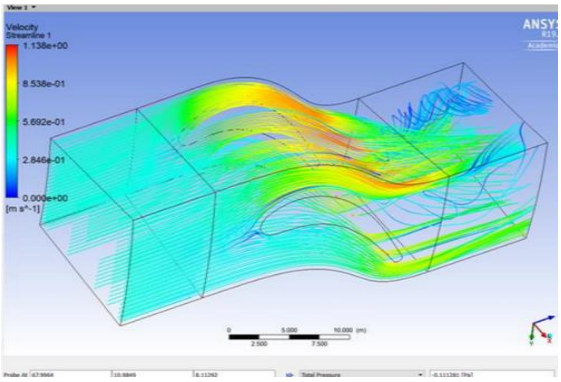

Figure 6: Velocity Contour on Turbine Bade

Table 2: Validation of Numerical results

Parameter	Value Calculated in the Paper	Value Calculated after Simulation	Error %	Additional Values used in Calculations
Velocity	0.36m/s	0.34m/s	5.50 %	μ= 1.46e-5 kg/m-s
Reynolds No	600000	554246.5	7.62 %	Re=600000 & rho=1.225
Nusselts No	836.1	784.7	6.10 %	Sc= 2.28
Sherwood No	1269.2	1191.2	6.14 %	sh= 0.023*(Re^0.8)*(Sc^(1/3))

In the results here we can clearly see that velocity has least error when compared to the paper simulations in Table 2. Thus, it is being considered as the primary value for baseline.

Other values also have an error less than 10%, making the simulation carried out to be in close approximation to the original experiment in [31] can be seen from Figure 3 & Figure 4.

CONCLUSIONS

Research to enhance the performance of the above model is being done justifying the title performance enhancement. This enhancement is to be carried out in three ways.

- By varying the profiles of the blade of axial flow turbine.
- By taking different turbulence models into consideration.
- By taking velocity into consideration which was assumed to be constant in the above paper.

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